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Short Communication

Maximization of seed production in CMS line of rice hybrids

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Hybrid rice has established its superiority over high yielding varieties in respect of growth, yield and tolerance to stresses. The impact of hybrid rice technology has been spectacular in China on rice production. In India 14 public and 8 private sector rice hybrids have been released for commercial cultivation [1, 2]. Non-availability of pure seed at reasonable cost, poor grain quality of hybrids and lack of specific resistance to some major pests and diseases are the major problems in further promoting hybrid rice technology in India [3]. The main cause of low hybrid seed production is poor seed set on the male sterile seed parent (A line) due to incomplete (about 70%) panicle exsertion. Maximum elongation of the last internode takes place at stage 8 of the panicle differentiation [5]. GA_3 has been a boon in solving the problem of panicle exsertion of the female lines.

In India, hybrid seed yield level of 1.5-2.0 t/ha has been obtained in experimental plots of different locations as reported by Directorate of Rice Research, Hyderabad [6]. In seed production studies at the Division of Seed Science and Technology, IARI, New Delhi during 1997-2000, an yield level of 2.8 to 3.1 t/ ha of CMS line, IR 58025A has been obtained with the application of GA_3 @ 135 g/ha in the planting ratio of 2:8 of B and A line [7]. There was 65% improvement in seed set of female parent using 150 g GA_3/ha, spraying 3-4 times in the concentration of 40-60 ppm [5]. Thus use of growth promoters to enhance the different characteristic floral parts, seed set and yield was considered critical for hybrid rice seed production. Hence, an attempt was made to study the possibilities in maximizing seed yield of CMS parent by further modifying the dose of GA_3 and planting ratio.

In the present study, one of the most popular CMS line, IR58025A (A line) was used for seed production with IR58025B (B line) as pollen parent. The experiment was conducted on 3.75 x 5.5 m^2 plots in 2:8(B:A) and 2:12(B:A) row ratios with 15, 20 and 30 cm spacing between A line rows, between A and B line rows and between B line rows, respectively and 15 cm plant to plant spacing at Indian Agricultural Research Institute, New Delhi during *kharif,* 2001. The treatments consisted of spray of GA_3 @ 90, 135, 180, 225 and 270 g/ha and without GA_3 spray as control. GA_3 was sprayed in two split doses in the ratio of 2:3 (i.e., 40 and 60 percent, respectively) on two consecutive days at 5% heading stage. The experiment was conducted in factorial design with RBD and 3 replications. The standard recommended package of practices was followed for growing the crop. Rope pulling was done two to three times a day at half an hour interval during peak anthesis period and it was continued for about two weeks.

Plant height, panicle exsertion, per cent seed set on CMS line was recorded on ten random plants per plot. Panicle exsertion (%) was determined on the basis of number of spikelets emerging out of leaf sheath divided by total number of spikelets in the panicle. Number of total tillers and productive tillers were also recorded. The floral characters *viz.,* spikelet-opening angle, stigma exsertion, stigma length, style length and anther length were recorded. Harvesting was done row-wise for each treatment. Seed yield/ plot was calculated by adding seed yield/row. The yield (kg/ha) was calculated based on plot size. Statistical analysis of data on the floral, morphological and yield attributing characters was done using factorial RBD. The correlation analysis among all floral characters, panicle exsertion and seed set was done.

Plant height of CMS IR58025A line recorded a progressive and significant increase with increasing dose of GA_3. It increased from 75 cm in control to 126 cm with the application of GA_3 @ 270 g/ha (Table 1). However, taller plants as a result of GA_3 application beyond 180 g/ha lodged. There was a significant increase in flag leaf angle with increasing dose of GA_3. Flag leaf angle increased from 20.9° in control to 33.8° with GA_3 spray @270 g/ha. A significant increase in total and productive tillers was recorded beyond the GA_3 dose of 135 g/ha (Table 1). GA_3 spray @ 270 g/ha increased total number of tillers to 16 from 12 (in control) and productive tillers to 11 from 9 (in control). Panicle exsertion increased from 76.6% in control to 94.2% in 270 g/ha GA_3. Application of GA_3 @ 90 g/ha exhibited non-significant increase in panicle exsertion over control. Significant increase in panicle exsertion was observed only at 135-270 g/ha GA_3 application. Significant increase in the total number of tillers, productive tillers and flag leaf angle with the increasing dose of GA_3 has been earlier [8, 9]. There was an enhanced panicle exsertion up to 95% with the application of GA_3 [9]. A positive correlation between plant height and dose of GA_3 was obtained by Virmani *et al.* [10]. Increase in plant height is essential for easy pollen movement from the pollen parent to the seed parent. But higher dose of GA_3 (beyond 180g/ha) increased the height of seed parent leading to lodging of plants and loss of seed yield.

Table 1. Effect of GA_3 on traits favouring outcorssing in CMS line IR58025A

Treatment	Plant height (cm)	Flag leaf angle(°)	Total no. of tillers	No. of productive tillers	Panicle exertion (%)
Control	75.0	20.9	11.7	9.4	76.6
GA_3@90g/ha	101.7	27.0	12.5	9.7	85.0
GA_3@135g/ha	110.9	27.4	12.7	10.0	87.7
GA_3@180g/ha	115.1	28.9	13.2	10.1	90.2
GA_3@225g/ha	121.4	29.7	14.0	10.7	91.9
GA_3@270g/ha	125.8	33.8	16.0	11.3	94.2
Mean	108.3	27.9	13.3	10.2	87.6
C.D. (p=0.05)	5.59	3.04	0.6	0.5	9.7

The spikelet-opening angle increased from 17° (control) to 29° with the application of GA_3 @ 270 g/ha. There was an increase of 1-3° in the spikelet-opening angle with every additional dose of 45 g/ha (Table 2). A significant difference in stigma exsertion with higher doses of GA_3 was recorded. The stigma exsertion ranged from 25.2% in control to 44.7% in 270 g GA_3/ha in A line. Style length increased significantly when GA_3 was applied @ 225 g/ha and above. The style length increased from 1.2 mm in control to 1.44 mm in GA_3 @ 270 g/ha (Table 2). Similarly stigma length increased significantly with GA_3 application @ 180 g/ha and above. It increased from 1.13 mm (control) to 1.40 mm (GA_3 @ 270 g/ha) (Table 2). The anther length increased up to 2.36 mm with GA_3 spray @ 270 g/ha as against 1.97 mm in control (Table 2). Several workers reported that GA_3

Table 2. Effect of GA_3 on floral characters of CMS line IR58025A and anther length of maintainer line IR58025B

Treatment	Spikelet opening angle (°)	Stigma exertion (%)	Style length (mm)	Stigma length (mm)	Anther length (mm)
Control	16.93	25.21	1.20	1.13	1.97
GA_3@90g/ha	20.60	27.84	1.22	1.18	2.04
GA_3@135g/ha	22.73	35.72	1.30	1.20	2.13
GA_3@180g/ha	24.30	35.20	1.30	1.25	2.20
GA_3@225 g/ha	25.10	37.40	1.36	1.32	2.30
GA_3@270 g/ha	28.70	44.71	1.44	1.40	2.36
Mean	23.05	34.54	1.29	1.25	2.18
C.D. (p = 0.05)	1.61	4.00	0.11	0.11	0.11

improves floral characters of rice in relation to outcrossing [8, 9, 11]. For floral character, there was linear increase with the increasing dose of GA_3. Increase in spikelet opening angle was recorded with application of GA_3 [12]. In the present study, maximum flag leaf angle (29°) was found when GA_3 @ 270 g/ha was applied as compared to control (17°). Higher flag leaf angle leading to its flattening facilitates higher pollen flow from pollen to seed parent. This also reduces cost of cultivation by elimination of flag leaf cutting, an usual practice in hybrid rice seed production. Flattening of flag leaf with GA_3 application

was reported by other workers [8, 9, 13 and 14]. Increase in anther length of the pollen parent was associated with higher number of pollen grains per anther Farmer *et al.*, [15]. Thus GA_3 spray induces higher pollen production and in turn availability of more pollen for fertilization. A positive correlation between stigma exsertion and dose of GA_3 was also reported [9].

The highest seed set of 57.8% was recorded with GA_3 @ 270 g/ha as compared to 41.1% in control (Table 3). The average percent seed set in seed parent decreased in case of 2:12 planting ratio as compared to that in 2:8 planting ratio. However, these differences were not significant. There was an increasing trend in percent seed set with increasing dose of GA_3, in both the planting ratios. Spraying with higher dose of GA_3 for three or four times at early heading stage improved per cent seed set of CMS parent up to 65% in China [12].

There was a significantly higher seed yield in 2:8 planting ratio as compared to that in 2:12 (Table 3). The seed yield increased significantly with application of GA_3 up to 135 and 180 g/ha in 2:8 and 2:12 planting ratios, respectively. A maximum yield of 1986 kg/ha was obtained in 180g/ha GA_3 in 2:8 planting ratio. However, it significantly decreased beyond the GA_3 dose of 180g/ha. A maximum seed yield of 1893kg/ha seed yield was obtained in 180 g/ha GA_3 in 2:12 planting ratio. An average seed yield of 2.4 to 2.9t/ha in Pusa 5A was obtained by Pandey *et al.* [8] with GA_3 @45 to 180g/ha. Similarly Jagadeeshwari *et al.* [9] reported an average yield of 2.7 to 3.1 t/ha with the application of 90 to 135g GA_3/ha in CMS line, IR 58025A. Out of four planting ratios maximum seed yield per unit area was obtained in 2:8 [16].

Environmental conditions play important role in seed production and favorable environmental condition leads to the high seed yield [9, 10]. The general seed yield, was higher and 2.43 t/ha seed yield was obtained without application of GA_3. This was attributed to favorable R.H. of 69-75%, maximum/minimum temperature of 35/25 and wind velocity of 4.8km/hr. In the present study the lower seed yield as compared to those reported by Pandey *et al.* [8] and Jagdeeswari *et al.* [9] was primarily due to high rainfall in first week of September during peak flowering (77mm) which resulted in pollen wash and less seed set (49.09% in 2:8 and 43.4% in 2:12 row ratio). Wind velocity of 6.95 km/hr, mean maximum temperature of 35.3°C and R.H. (69-75), higher sunshine hours in first week of September during flowering were unfavorable for higher seed set and yield (Table 5). In the present study, a yield level 1.339 t/ha was observed in 2:8 row ratio in control. This could be

Table 3. Effect of GA_3 on seed set (%) and seed yield (kg/ha) in CMS line IR58025A in two planting ratios

Treatment/row ratio	Seed set (%)		Mean	Seed yield (kg/ha)		Mean
	2:8	2:12		2:8	2:12	
Control	41.1	36.3	38.7	1339.1	1052.4	1180.8
GA_3 @ 90 g/ha	45.0	40.1	42.5	1560.4	1186.7	1373.6
GA_3 @ 135 g/ha	48.9	42.9	45.9	1876.6	1423.4	1650.0
GA_3 @ 180 g/ha	52.2	46.8	49.5	1986.3	1893.9	1940.1
GA_3 @ 225 g/ha	49.3	45.0	47.2	1538.5	1267.5	1403.0
GA_3 @ 270 g/ha	57.8	49.9	53.8	1768.5	1772.4	1770.5
Mean	49.1	43.5	47.3	1678.2	1432.7	1561.4
C.D. (0.05)						
	Treatment		7.67		65.0	
	Row ratio		N.S.		112.7	
	Interaction		18.78		159.3	

Table 4. Meteorological observation during flowering period (first & second week of September 2001)

Date of transplanting	13.07.2001
Date of panicle emergence (5%)	03.09.2001
Mean max. temperature (°C)	35.3
Mean min. temperature (°C)	25.15
Temperature range (°C)	21.9-35.4
Mean relative humidity (%)	72
Relative humidity (max.) range (%)	**69-75**
Total rainfall (mm)	**77.4**
Mean sunshine (hours/day)	8.15
Mean wind velocity (km/hr)	6.95

increased to 1.876 t/ha with the application of 135 g/ha and to 1.986 t/ha with 180 g/ha GA_3 application in 2:8 planting ratio in an unfavorable weather conditions. Thus, there was an improvement of hybrid seed yield with the application of GA_3 up to 180 g/ha. Beyond this dose increase in seed yield was not observed. In higher level of GA_3 there was increase in the height of the seed parent which limited free pollen movement. Also at higher doses of GA_3 lodging of plants and phytotoxicity of leaves were noticed. This reduced the photosynthate supply to the sink at the latter stage.

Significant positive correlation was found between seed yield and seed set with other flower characters [8]. In the present study per cent seed set and stigma length showed high association with style length and stigma exsertion per cent (Table 4). Style length, spikelet opening angle, stigma exsertion, panicle exsertion and seed set had greater significant association with each other. Except stigma length all the characters had significant correlation with per cent seed set. Virmani and Atwal [17] reported a positive correlation between stigma exsersion and stigma length. Namai and Kato [18] reported that stigma exsertion percentage was positively correlated with other floral characteristics such as pistil, stigma, angle between lemma and palea. A high significant correlation between stigma exsertion and seed set was also reported by Elsy *et al.* [19] and Ramaligam *et al.* [20].

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Table 5. Correlation coefficient between different floral characters and seed set (%) of CMS line

	Style length (cm)	Spikelet opening angle (°)	Stigma exsertion(%)	Panicle exsertion(%)	Seed set (%)
Stigma length (mm)	0.552*	0.365	0.461	0.299	0.353
Style length (cm)	1.00	0.943**	0.921**	0.920**	0.914**
Spikelet opening angle (°)		1.00	0.926**	0.923**	0.938**
Stigma exsertion (%)			1.00	0.877**	0.893**
Panicle exsetion (%)				1.00	0.903**
Seed set (%)					1.00

*and**indicate significance of correlation coefficient at 5% and 1% probability of error, respectively.

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